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Title: ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING RECEIVER DEVICE

VERIFIED TRANSLATION OF PRIORITY DOCUMENT

The undersigned, of the below address, hereby certifies that he/she well knows both the English and Japanese languages, and that the attached is an accurate translation into the English language of the Certified Copy, filed for this application under 35 U.S.C. Section 119 and/or 365, of:

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[Title of the Invention] ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING RECEIVER

[Scope of Claim]

[Claim 1] An OFDM receiver, comprising:

means for receiving an OFDM signal setting, in the same time direction, the arrangements on the frequency axis, of a plurality of information signals and a plurality of known signals in which the plural known signals are dispersed among the plural known signals, the information signal is allocated in the frequency band lower than the frequency of the known signals in the lowest frequency side among the plural known signals and the information signal is allocated in the frequency band higher than the known signals in the highest frequency side among the plural known signals, and for respectively extracting the information signals and known signals from this OFDM signal;

means for calculating a transmission path response of the known signal using the extracted known signals;

means for estimating the transmission path characteristics, using the transmission path response of the known signals, of the information signal allocated among the known signals, the information signal allocated in the lower frequency side of the frequency and the information signal allocated in the higher frequency side of the frequency; and

means for compensating for amplitude and phase of the extracted information signal using the transmission

characteristic of the estimated information signals.

[Claim 2] An OFDM receiver, comprising:

means for receiving an OFDM signal setting, in the same time direction, the arrangements on the frequency axis, of a plurality of information signals and a plurality of known signals in which the plural known signals are dispersed among the plural known signals, the information signal is allocated in the frequency band lower than the frequency of the known signals in the lowest frequency side among the plural known signals and the information signal is allocated in the frequency band higher than the known signals in the highest frequency side among the plural known signals, and for respectively extracting the information signals and known signals from this OFDM signal;

means for calculating the transmission response of the known signal using the calculated known signal; and

means for estimating with the linear interpolation, using the transmission path response of the calculated known signals, the transmission characteristics of the information signal allocated among the known signals, the information signal allocated in the lower frequency side of the frequency and the information signals allocated in the higher side of the frequency; and

means for compensating for amplitude and phase of the extracted information signal using the transmission characteristics of the estimated information signals.

[Claim 3] An OFDM receiver as claimed in claim 2, wherein

the means for estimating transmission characteristics of the information signals estimates the transmission path characteristic of the information signal allocated in the lower side of the frequency with the transmission path response of the known signal in the lowest frequency side and the transmission path response of the known signal adjacent to the high side of frequency than the known signal and also estimates the transmission path characteristic of the information signal allocated in the higher side of the frequency with the transmission path response of the known signal in the higher side of the highest frequency and the transmission path response of the known signal adjacent to the lower side of frequency than the known signal.

[Claim 4] An OFDM receiver comprising:

means for receiving an OFDM signal setting, in the same time direction, the arrangements on the frequency axis, of a plurality of information signals and a plurality of known signals in which the plural known signals are dispersed among the plural known signals, the information signal is allocated in the frequency band lower than the frequency of the known signals in the lowest frequency side among the plural known signals and the information signal is allocated in the frequency band higher than the known signals in the highest frequency side among the plural known signals, and for respectively extracting the information signals and known signals from this OFDM signal;

means for calculating a transmission path response

of the known signal using the extracted known signals;

means for estimating, through compensation with the Sinc function using the transmission path response of the calculated known signal, the transmission path characteristic of the information signal allocated between the known signals, the information signal allocated in the lower side of frequency and the information signal allocated in the higher side of frequency; and

means for compensating for amplitude and phase of the information signals extracted using the transmission path characteristic of the estimated information signals.

[Claim 5] An OFDM receiver as claimed in claim 4, wherein the means for estimating the transmission path characteristic of information signals obtains respective transmission path responses of the extracted known signals to match the transmission response of the known signal with the maximum value of the Since function and executes the interpolation by combining respective Sinc functions passing almost the zero point of the transmission path response of the other known signals.

[Detailed Description of the Invention]

[Field of the Invention]

The present invention relates to an orthogonal frequency division multiplexing (OFDM) receiver in the communication system utilizing the orthogonal frequency division multiplexing system.

[Background Art]

Recent radio communication systems require to transmit large capacity data such as video information or the like as the digital value not only with wire transmission system but also with radio transmission system. In this case, it is essential to introduce not only the Phase Shift Keying system to modulate the phase with the information by utilizing difference of phase such as BPSK and QPSK or the like but also the Quadrature Amplitude Modulation system to modulate the phase and amplitude with the information by utilizing differences of phase and amplitude such as 16QAM and 64QAM or the like. The signals modulated with the QAM method such as 16QAM and 64QAM is transmitted from a transmitter and is then received with a receiver through the transmission path. Thereby, the original data can be demodulated through the synchronous detection.

In this case, when the wired transmission path is used, any problem does not occur, but when the radio transmission link is established, a large distortion is generated in both amplitude and phase of the received signal due to the transmission path deteriorated, for example, with fading. Therefore, as a method of alleviating distortion with the transmission path, there is proposed a technique for holding the same known pilot signal (known signal) in both transmitter and receiver, transmitting such pilot signal from the transmitter, obtaining the transmission path response using the pilot signal received with the receiver and the pilot signal held in the receiver and then estimating the

transmission by interpolating the transmission path response in order to compensate for both amplitude and phase of the received data signal (information signal).

For example, JP-A No. H11-163822 describes the technique that is utilized to the communication system signal using the OFDM system to compensate for distortion in both amplitude and phase of the data signal included in the received OFDM signal.

[Problem to be Solved]

The above prior art discloses an OFDM receiver used in the digital broadcasting system using the ground wave. Therefore, it is a precondition that the format of OFDM signal in the European DVB-T system or the like as illustrated in Fig. 18 is used. In Fig. 18, the vertical direction indicates the time (symbol), while the horizontal direction indicates frequency (carrier). Moreover, white circles in the same figure define data symbols (data signals), while the black circles define the pilot symbols (pilot signals). The pilot symbol is transmitted in every 12 carrier frequencies and is cyclically allocated so that the same sub-carrier frequency is attained after the four symbols. The OFDM receiver disclosed in above related art compensates for distortion of the amplitude and phase of the received data signal and performs equalization on the frequency axis for the OFDM signal of the format illustrated in Fig. 18.

As the format of OFDM signal, there is proposed the OFDM signal format for MMAC (Multimedia Mobile Access

Communication) in addition to the format for the ground digital broadcast explained above. In this FDM signal format, the data signals (white circles in the figure) of 0 to 4, 5 to 17, 18 to 29, 30 to 42, 43 to 47 are allocated in the frequency direction as illustrated, for example, in Fig. 19 and the pilot signals (black circles in the figure) are also dispersed among such data signals. Moreover, these allocations are identical in the time direction. In the case of this OFDM signal format, the data signals of 0 to 4 are allocated in the side of frequency lower than the pilot signal in the lowest frequency side among the four pilot signals, while the data signals of 43 to 47 are allocated in the side of frequency higher than t he pilot signal in the highest frequency side among four pilot signals. Since the OFDM signal format of Fig. 18 is different from that of Fig. 19 as explained above, it is impossible to adequately compensate for both amplitude and phase of the received data signal for the OFDM signal format for MMAC as illustrated in Fig. 19 in the OFDM receiver disclosed in the reference H11-163822.

The present invention is proposed considering the problems of the related art explained above and therefore the object of the present invention is to provide an OFDM receiver that can properly compensate for both amplitude and phase of the received data for the OFDM signal format for MMAC.

[Solution]

For attaining the above object, in the present invention according to claim 1, an OFDM receiver comprises:

means for receiving an OFDM signal in an OFDM signal format for MMAC and extracting information signals and known signals from this OFDM signal;

means for calculating a transmission path response of the known signal using the extracted known signals;

means for estimating the transmission path characteristics, using the transmission path response of the known signals, of the information signal allocated among the known signals, the information signal allocated in the lower frequency side of the frequency and the information signal allocated in the higher frequency side of the frequency; and

means for compensating for amplitude and phase of the extracted information signal using the transmission characteristic of the estimated information signals.

According to the present invention, the amplitude and phase of the received information signals can be properly corrected relative to the OFDM signal format for MMAC.

In this instance, the estimation of the transmission path characteristics of the information signals may be attained by a linear interpolation claimed in claim 2 or an interpolation using Sinc functions claimed in claim 5.

If the linear interpolation is used, as claimed in claim 3, it is preferred to estimate the transmission path characteristic of the information signal allocated in the lower side of the frequency with the transmission path response of the known signal in the lowest frequency side

and the transmission path response of the known signal adjacent to the high side of frequency than the known signal and to also estimate the transmission path characteristic of the information signal allocated in the higher side of the frequency with the transmission path response of the known signal in the higher side of the highest frequency and the transmission path response of the known signal adjacent to the lower side of frequency than the known signal. As a result, the transmission path characteristic of the information signal, which is not at a position between the known signals, can be estimated.

If the interpolation by the Sinc functions is used, as claimed in claim 5, it is preferred to interpolate by obtaining respective transmission path responses of the extracted known signals to match the transmission response of the known signal with the maximum value of the Since function and combining respective Sinc functions passing almost the zero point of the transmission path response of the other known signals.

[Embodiment of the Invention]

Fig. 1 illustrates a structure of the OFDM receiver used in the communication system utilizing the OFDM signal format for MMAC of Fig. 19. This OFDM receiver is constituted of an antenna 1, a receiving unit 2, FFT (High speed Fourier Transforming) processing unit 3, a data extracting unit 4, a pilot extracting unit 5, a pilot generating unit 6, a complex dividing unit 7, an interpolating

unit 8, a complex dividing unit 9 and a demodulating unit 10.

The OFDM signal transmitted in the signal format of the OFDM signal of Fig. 19 is received with the antenna 1. The receiving unit 2 converts the OFDM signal received with the antenna 1 to the baseband OFDM signal through the RF signal receiving process and timing regenerating process or the like. The FFT processing unit 3 converts the baseband OFDM signal processed in the receiving unit 2 to the Y (1, k) [where, k = 0 to 51] signal in the frequency axis direction. Numeral 1 indicates a symbol and k indicates the signal number arranged in the frequency axis direction.

The data extracting unit 4 extracts only the data signal Y(1, kd) [where, kd = 0 to 47] in the OFDM signal format of Fig. 19 from the signal in the frequency axis direction processed in the FFT processing unit 3. Moreover, the pilot extracting unit 5 extracts only the pilot signal Y(1, kp) [where, kp = 0 to 3] in the OFDM signal format of Fig. 19 from the signal in the frequency axis direction processed in the FFT processing unit 3.

Meanwhile, the pilot generating unit 6 generates a pilot signal X (1, kp) [where, kp = 0 to 3] having the same amplitude and phase as that in the transmitting side. The complex dividing unit 7 executes the complex division for the pilot signal from the pilot extracting unit 5 with the pilot signal from the pilot generating unit 6 to calculate the transmission path response (1, kp) [where, kp = 0 to 3] of the pilot signal.

The interpolating unit 8 calculates the transmission path estimation value H' (l, k) [where, k = 0 to 47] estimating the transmission path of the data signal through the interpolation using the transmission path response of the pilot signal. In more practical, the interpolating unit 8 calculates the transmission path estimation path H' (l, k) [where, k = 0 to 47] estimating the transmission path characteristic of the data signals of 0 to 4, 5 to 17, 18 to 29, 30 to 42, 43 to 47 through the interpolation using the four pilot signals of Fig. 19. In this case, as the interpolation, for example, the linear interpolation or interpolation with the Sinc function may be used.

The complex dividing unit 9 executes the complex division for the data signal from the data extracting unit 4 with the transmission path estimation value estimating the transmission path of the data signal from the interpolating unit 8 to calculate the data signal Y' (l, kd) [where, kd = 0 to 47] compensated in the amplitude and phase.

The demodulating unit 10 executes the demodulation of data signal using the data signal outputted from the complex dividing unit 9 and then outputs a digital data stream.

Next, as the interpolation in the interpolating unit 8, the embodiment of the linear interpolation and the embodiment of the interpolation with the Sinc function will be explained respectively.

(Embodiment of the linear interpolation)

In this embodiment, in the interpolating unit 8,

as illustrated in Fig. 2, the transmission path estimation value H′(l, k) [where, k = 0 to 47] estimating the transmission path of the data signal is calculated by the linear interpolation using the transmission path response H(l,kp) [where, kp = 0 to 3] of the pilot signal.

Fig. 3 illustrates a practical structure of the interpolating unit 8 for linear interpolation.

This linear interpolating unit 8 is constituted of adding units 21 to 23, dividing units 24 to 26 and transmission path estimating units 27 to 31. The transmission path response H (l, kp) [where, kp = 0 to 3] of pilot signal calculated in the complex dividing unit 7 is inputted to the adding unit 21, adding unit 22 and adding unit 23. The adding units 21, 22, 23 respectively calculate difference of the transmission path response of the adjacent pilot signals. An output of the adding unit 21 is then inputted to the dividing unit 24 and is then divided with a constant 14 because an interval of the pilot signals in both sides of the data signals 5 to 17 is 14. The result of division p01 indicates a gradient between the pilot signals. In the same manner, an output of the adding means 22 is inputted to the dividing unit 25 and is then divided with a constant 13. Moreover, an output of the adding unit 23 is inputted to the dividing unit 26 is then divided with 14. Results of division p12, p23 are outputted respectively from the dividing units 25, 26.

The transmission path estimating unit 27

calculates the transmission path estimation values H'(1, 0) to H'(1, 4) of the data signal of Fig. 2 using the value p01 outputted from the dividing unit 24 and the transmission path response H(1, 0) of the pilot signal, while the transmission path estimating unit 28 calculates the transmission path estimation values H'(1, 5) to H'(1, 17) of the data signal of Fig. 2 using the value p01 outputted from the dividing unit 24 and the transmission path response (1, 0) of the pilot signal, the transmission path estimating unit 29 calculates the transmission path estimation values H'(1, 18) to H'(1, 29) of the data signal of Fig. 2 using the value p12 outputted from the dividing unit 25 and the transmission path response H (1, 1) of the pilot signal, the transmission path estimating unit 30 calculates the transmission path estimation values H'(1, 30) to H'(1, 42) of the data signal of Fig. 2 using the value p23 outputted from the dividing unit 26 and the transmission path response H(1, 2) of the pilot signal, and the transmission path estimating unit 31 calculates the transmission path estimation values H'(1, 43) to H'(1, 47) of the data signal of Fig. 2 using the value p23 outputted from the dividing unit 26 and the transmission path response H(1, 3) of the pilot signal.

Fig. 4 illustrates a practical structure of the transmission path estimating unit 27. In this transmission path estimating unit 27, the value p01 outputted from the dividing unit 24 is sequentially subtracted from the transmission path response H(1, 0) of the pilot signal to

calculate the transmission path estimation values H′(1, 4) to H′(1, 0) of the data signal.

In more practical, the adding unit 271 calculates the transmission path estimation value H′(1, 4) from a difference between the transmission path response H(1, 0) of the pilot signal and the value p01. Moreover, the adding unit 272 calculates the transmission path estimation value H′(1, 3) from a difference between the transmission path estimation value H′(1, 4) calculated in the adding unit 271 and the value p01. Moreover, the adding unit 273 calculates the transmission path estimation value H′(1, 2) from a difference between the transmission path estimation value H′(1, 3) calculated in the adding unit 272 and the value p01. Moreover, the adding unit 274 calculates the transmission path estimation value H′(1, 1) from a difference between the transmission path estimation value H′(1, 2) calculated in the adding unit 273 and the value p01. Moreover, the adding unit 275 calculates the transmission path estimation value H′(1, 0) from a difference between the transmission path estimation value H′(1, 1) calculated in the adding unit 274 and the value p01.

Fig. 5 illustrates a practical structure of the transmission path estimating unit 28. In this transmission path estimating unit 28, the value p01 outputted from the dividing unit 24 is sequentially added to the transmission path response H(1, 0) of the pilot signal to calculate the transmission path estimation values H′(1, 5) to H′(1, 17) of

the data signal.

In more practical, the value p01 is multiplied with a constant 1 of the multiplying unit 281 and subsequently the value obtained is then added to the transmission path response H(1, 0) of the pilot signal in the adding unit 284. Moreover, the value p01 is multiplied with a constant 2 of the multiplying unit 282 and subsequently the value obtained is then added to the transmission path response H(1, 0) of the pilot signal in the adding unit 285 to calculate the transmission path estimation value H'(1, 6). Thereafter, similar multiplication and adding processes are performed to calculate the transmission path estimation value H'(1, 17) from the multiplying unit 283 and adding unit 286 in the final stage.

Fig. 6 illustrates a practical structure of the transmission path estimating unit 29. The structure of this transmission path estimating unit 29 is similar to that of Fig. 5, comprising the multiplying units 291, 292, 293 and adding units 294, 295, 256 to calculate the transmission path estimation values H'(1, 18) to H'(1, 29) of the data signal by sequentially adding the value p12 outputted from the dividing unit 25 to the transmission path response H(1, 1) of the pilot signal.

Fig. 7 illustrates a practical structure of the transmission path estimating unit 30. The structure of this transmission path estimating unit 30 is similar to that of Fig. 5, comprising the multiplying units 301, 302, 303 and

adding units 304, 305, 306 to calculate the transmission path estimation values H' (1, 30) to H' (1, 42) of the data signal by sequentially adding the value p23 outputted from the dividing unit 26 to the transmission path response H(1, 2) of the pilot signal.

Fig. 8 illustrates a practical structure of the transmission path estimating unit 31. The structure of this transmission path estimating unit 31 is similar to that of Fig. 4, comprising the adding units 311, 312, 313, 314, 315 to calculate the transmission path estimation values H' (1, 43) to H' (1, 47) of the data signal by sequentially adding the value p23 outputted from the dividing unit 26 from the transmission path response H(1, 3) of the pilot signal.

As explained above, the transmission path estimation values H' (1, 5) to H' (1, 17), H' (1, 18) to H' (1, 29), H' (1, 30) to H' (1, 42) located at the positions sandwiched respectively with the four pilot signals are calculated through the linear interpolation using the transmission path response of the four pilot signals, moreover the transmission path estimation values H' (1, 0) to H' (1, 4) are calculated, for the data signals in the lower frequency side not sandwiched with the pilot signals, with the linear interpolation using the transmission responses of the adjacent two pilot signals in the frequency side higher than such lower frequency, and the transmission path estimation values H' (1, 43) to H' (1, 47) can be calculated, for the data signal in the higher frequency side not sandwiched with the pilot signals, by the

linear interpolation using the transmission path response of the adjacent two pilot signals in the frequency side lower than such frequency. Accordingly, even in the communication system using the OFDM signal format for MMAC of Fig. 19, the transmission path estimation values H' (1, k) [where, k = 0 to 47] estimating the transmission path characteristic of each data signal can be attained.

Fig. 9 illustrates a bit error rate (BER) obtained with the computer simulation in the case where the two waves Reyleigh fading environment is assumed for the transmission path in regard to the OFDM receiver explained above.

Moreover, as the main parameters for simulation, the maximum Doppler frequency is set to 52Hz, the number of sub-carriers of OFDM signal is set to 52 (48 data carrier + 4 pilot carriers), the effective symbol length is set to 3.2 μ s, the guard interval length is set to 800 ns and the modulation system is set to 16QAM.

From this Fig. 9, it can be understood, when the data signal is equalized in the embodiment explained above, the higher the average C/N (power ratio of carrier and noise) become, the lower the bit error rate is and moreover the larger DUR (power ratio of direct wave and delayed wave) is, the lower the bit error rate becomes.

(Embodiment of the interpolation with Sin function)

In this embodiment, as illustrated in Fig. 10, the transmission path estimation values H' (1, k) [where, k = 0 to 47] estimating the transmission path of data signal is

calculated in the interpolating unit 8 through the interpolation with the Sinc function using the transmission path response H(1, kp)[where, kp = 0 to 3].

Here, the Sinc function is expressed as sin(x)/x. Moreover, the curve A in Fig. 10 passes the point where the maximum value matches with the transmission path response H(1, 0) and the transmission path response H(1, 1), transmission response H(1, 2), transmission response (1, 3) are almost zero, while the curve B passes the point where the maximum value matches with the transmission response H(1, 1) and the transmission path response H(1, 0), transmission path response H(1, 2) and transmission path response (1, 3) are almost zero and the curve C passes the point where the maximum value matches with the transmission path response H(1, 2), the transmission path response H(1, 0), transmission path response H(1, 1) and transmission path response H(1, 3) are almost zero and the curve D passes the point where the maximum value matches with the transmission path response H(1, 3) and the transmission path response H(1, 0), transmission path response H(1, 1) and transmission path response H(1, 2) are almost zero.

Fig. 11 illustrates a practical structure of the interpolating unit 8 for executing interpolation with the Sinc function.

The interpolating unit 8 using the Sinc function is constituted of the estimation processing units 41, 42, 43, 44. These estimation processing units 41, 42, 43, 44 executes

the interpolation with the Sinc function using the transmission path responses H(1, kp) [where, kp = 0 to 3] of the pilot signal and respectively outputs the transmission path estimation values H′(1, k) [where, k = 0 to 47] estimating the transmission path of data signal.

The estimation processing units 41, 42, 43, 44 are formed in the identical structure and the structure and operations thereof will be explained with reference to the k-th estimation processing unit 43. Fig. 12 illustrates the practical structure of the k-th estimation processing unit 43.

In Fig. 12, the constant value k of the transmission path estimation value H′(1, k) of the data signal is inputted to a coefficient α arithmetic circuit 432, a coefficient β arithmetic circuit 433, a coefficient γ arithmetic circuit 434 and a coefficient ε coefficient arithmetic circuit 435.

In the coefficient α arithmetic circuit 432, as illustrated in Fig. 13, the constant value 5 of the block 4321 is subtracted from a constant value k, the result of subtraction is multiplied with a value of the multiplying unit 4322 and the result of multiplication is defined as α. This value α is then inputted to the Sinc function unit 436 illustrated in Fig. 12 and a value of the Sinc function for the value α can be obtained in this Sinc function unit 436. Thereby, a value of the Since function for the k-th data signal can be obtained on the curve A of Fig. 10. Here, a value of Sinc function is multiplied with the transmission path

response H(1, 0) of the pilot signal in the multiplying unit 450. The result of multiplication becomes a relation value for the transmission path estimation value H' (1, k) of the k-th data signal depending on the transmission response H(1, 0) of the pilot signal.

Moreover, in the coefficient β arithmetic circuit 433, as illustrated in Fig. 14, the constant value 19 of the block 4331 is subtracted from a constant value k and the result of subtraction is multiplied with a value of the multiplying unit 4332 and the result of multiplication is defined as β. This value β is inputted to the Sinc function unit 437 of Fig. 12 and a value of Sinc function for the value β is obtained in the Sinc function unit 437. Thereby, a value of the Sinc function for the k-th data signal can be obtained on the curve B of Fig. 10. A value of the Since function is multiplied with the transmission path response H(1, 1) of the pilot signal in the multiplying unit 451. The result of this multiplication becomes a relation value for the transmission path estimation value H' (1, k) of the k-th data signal depending on the transmission path response H(1, 1) of the pilot signal.

Moreover, in the coefficient γ arithmetic circuit 434, as illustrated in Fig. 15, the constant value 32 of the block 4341 is subtracted from a constant value k, the result of subtraction is multiplied with a value of the multiplying unit 4342 and the result of multiplication is defined as γ. This value γ is inputted to the Sinc function

unit 438 of Fig. 12 and a value of the Sinc function for the value γ can be obtained in the function unit 438. Thereby, a value of the Sinc function for the k-th data signal can be obtained on the curve C of Fig. 10. A value of the Since function is multiplied with the transmission path response H(1, 2) of the pilot signal in the multiplying unit 452. The result of multiplication becomes a relation value for the transmission path estimation value H' (1, k) of the k-th data signal depending on the transmission path response H(1, 2) of the pilot signal. Moreover, in the coefficient ε arithmetic circuit 435, as illustrated in Fig. 16, the value 46 of the block 4351 is subtracted from a constant value k, the result of subtraction is multiplied with a value of the multiplying unit 4352 and the result of multiplication is defined as ε. This value is then inputted to the Since function unit 439 of Fig. 12 to obtain a value of the Sinc function for the value ε in the Sinc function unit 439. Thereby, a value of the Sinc function for the k-th data signal can be obtained on the curve D of Fig. 10. A value of the Sinc function is multiplied with the transmission path response H(1, 3) of the pilot signal in the multiplying unit 453. The result of multiplication becomes a relation value for the transmission path estimation value H' (1, k) of the k-th data signal depending on the transmission path response H(1, 3) of the pilot signal.

Thereafter, the transmission path estimation value H' (1, k) of the k-th data signal can be obtained by adding

the result of multiplication of the multiplying units 450 to 453 in the adding unit 454.

As explained above, the transmission path estimation value H′(1, k) [where, k = 0 to 47] estimating the transmission path of the data signal can be calculated by executing the interpolating with the Sinc function using the transmission path response H(1, kp) [where, kp = 0 to 3] of the pilot signal.

Fig. 17 illustrates a bit error rate (BER) through the computer simulation in the case where the transmission path is assumed under the 2-wave Rayleigh fading environment for the OFDM receiver.

Moreover, as the main parameters for simulation, the maximum Doppler frequency is set to 52Hz, number of sub-carriers of OFDM signal is set to 52 (48 data carriers + 4 pilot carriers), effective symbol length is set to 3.2 μs, the guard interval length is set to 800ns and the modulation system is set to 16QAM.

From Fig. 17, it can be understood that when the data signal is equalized with the embodiment explained above, the higher the average C/N (power ratio of carrier and noise) is, the lower the bit error rate becomes and moreover the larger the DUR (ratio of direct wave and delay wave) is, the lower the bit error rate becomes.

[Brief Description of the Drawings]

[Fig. 1] is a diagram illustrating a structure of the OFDM receiver in relation to an embodiment of the present

invention.

[Fig. 2] is a diagram for explaining the linear interpolation.

[Fig. 3] is a diagram illustrating a structure of the interpolation unit 8 for the linear interpolation.

[Fig. 4] is a diagram for explaining the embodied structure of a transmission path estimation unit 27 of Fig. 3.

[Fig. 5] is a diagram illustrating the embodied structure of a transmission path estimation unit 28 of Fig. 3.

[Fig. 6] is a diagram illustrating the embodied structure of a transmission path estimation unit 29 of Fig. 3.

[Fig. 7] is a diagram illustrating the embodied structure of a transmission path estimation unit 30 of Fig. 3.

[Fig. 8] is a diagram illustrating the embodied structure of a transmission path estimation unit 31 of Fig. 3.

[Fig. 9] is a diagram illustrating the result of simulation of the bit error rate (EBR) for the average C/N of the OFDM receiver in the embodiment having executed the linear interpolation.

[Fig. 10] is a diagram explaining the interpolation with the Sinc function.

[Fig. 11] is a diagram illustrating a structure

of the interpolation unit 8 for the interpolation with the Sinc function.

[Fig. 12] is a diagram illustrating a structure of the kth estimation process unit 43 of Fig. 11.

[Fig. 13] is a diagram illustrating a structure of an arithmetic circuit 432 of the coefficient α of Fig. 12.

[Fig. 14] is a diagram illustrating a structure of an arithmetic circuit 433 of the coefficient β of Fig. 12.

[Fig. 15] is a diagram illustrating a structure of an arithmetic circuit 434 of the coefficient γ of Fig. 12.

[Fig. 16] is a diagram illustrating a structure of an arithmetic circuit 435 of the coefficient ε of Fig. 12.

[Fig. 17] is a diagram illustrating the result of simulation of the bit error rate (EBR) for the average C/N of the OFDM receiver in the embodiment having executed the linear interpolation with the Sinc function.

[Fig. 18] is a diagram illustrating an allocation example of the OFDM signal format in the European DVB-T system or the like.

[Fig. 19] is a diagram illustrating an allocation example of the OFDM signal format for MMAC.

[Explanation of Reference Numerals]

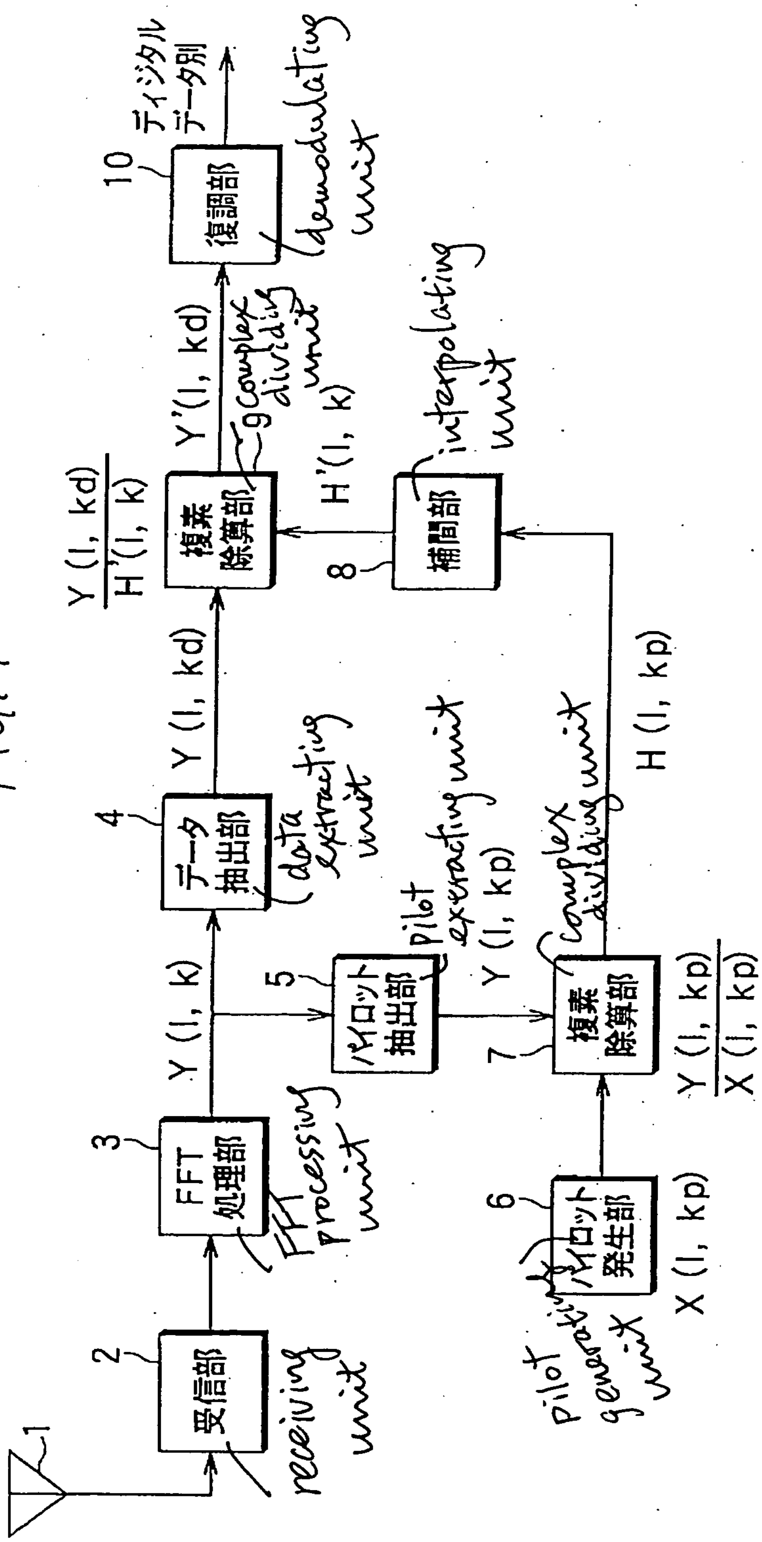
1 - antenna, 2 - receiving unit, 3 - FFT (Fast Fourier Transorm) processing unit, 4 - data extracting unit, 5 - pilot extracting unit, 6 - pilot generating unit, 7 - complex dividing unit, 8 - interpolating unit (linear interpolating unit, interpolating unit by Sinc function), 9 - complex dividing

unit, and 10 - demodulating unit.

【書類名】　　　　　図面

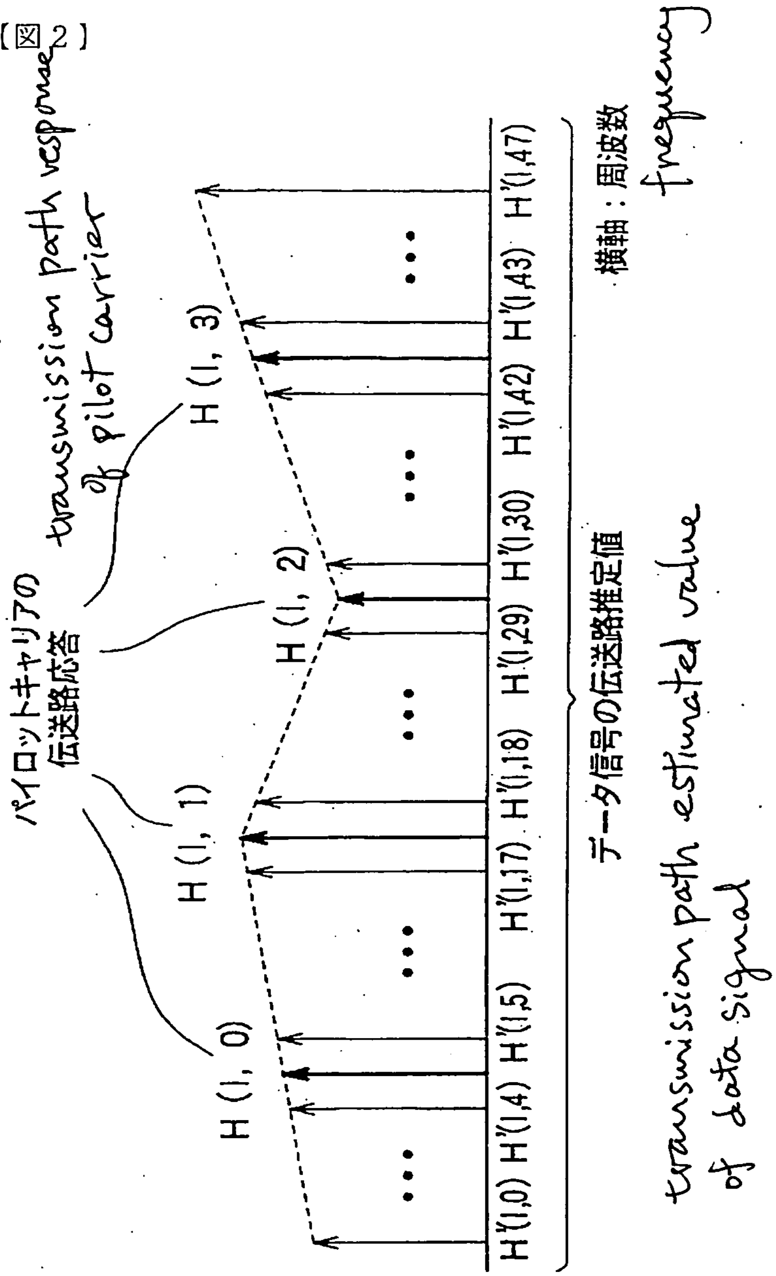
【図１】

FIG. 1



【図２】

FIG. 2


パイロットキャリアの
伝送路応答
transmission path response
of pilot carrier
H (1, 0)
H (1, 1)
H (1, 2)
H (1, 3)
H'(1,0) H'(1,4) H'(1,5)
H'(1,17) H'(1,18)
H'(1,29) H'(1,30)
H'(1,42) H'(1,43) H'(1,47)
データ信号の伝送路推定値
transmission path estimated value
of data signal
横軸：周波数
frequency

【図３】

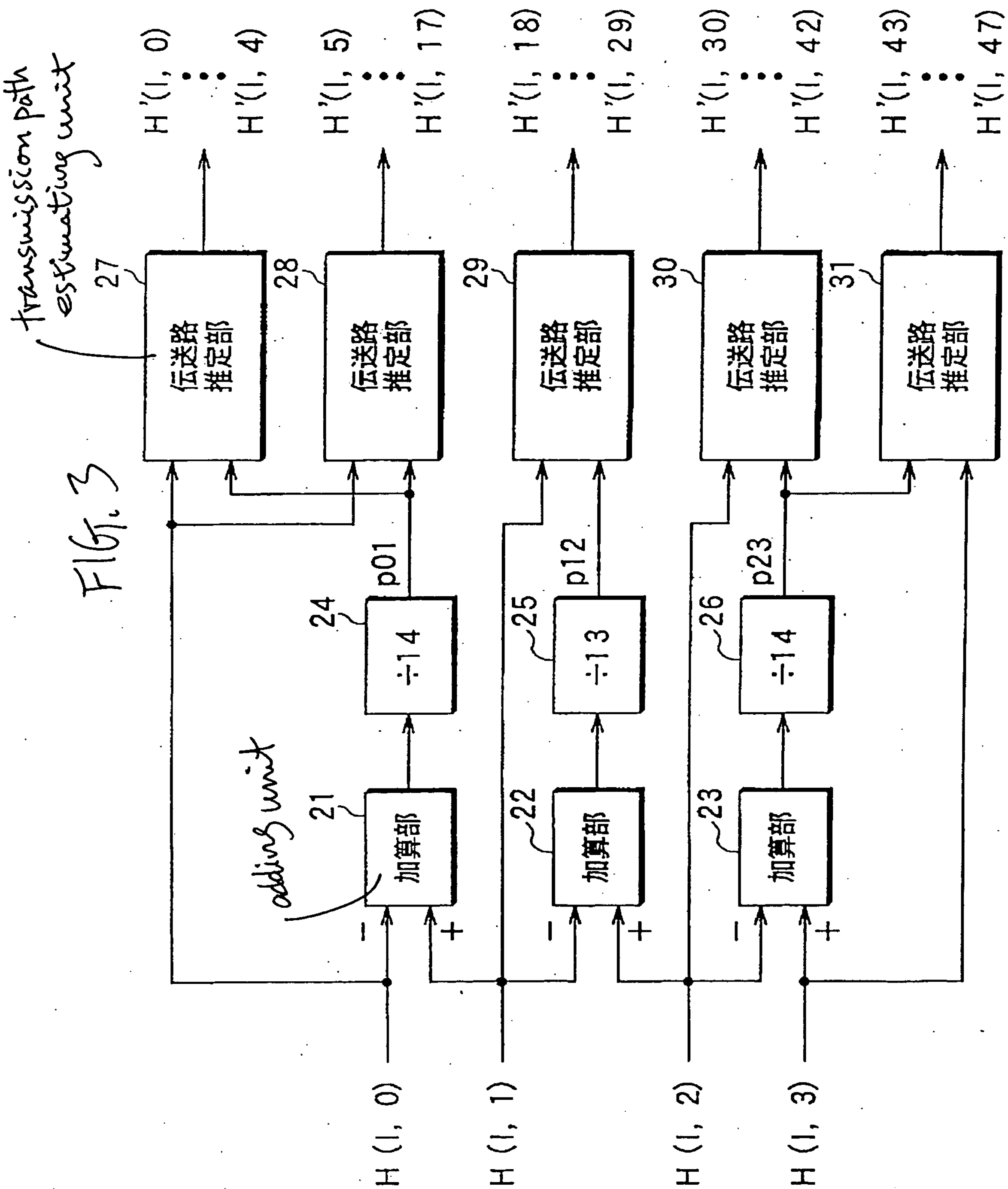
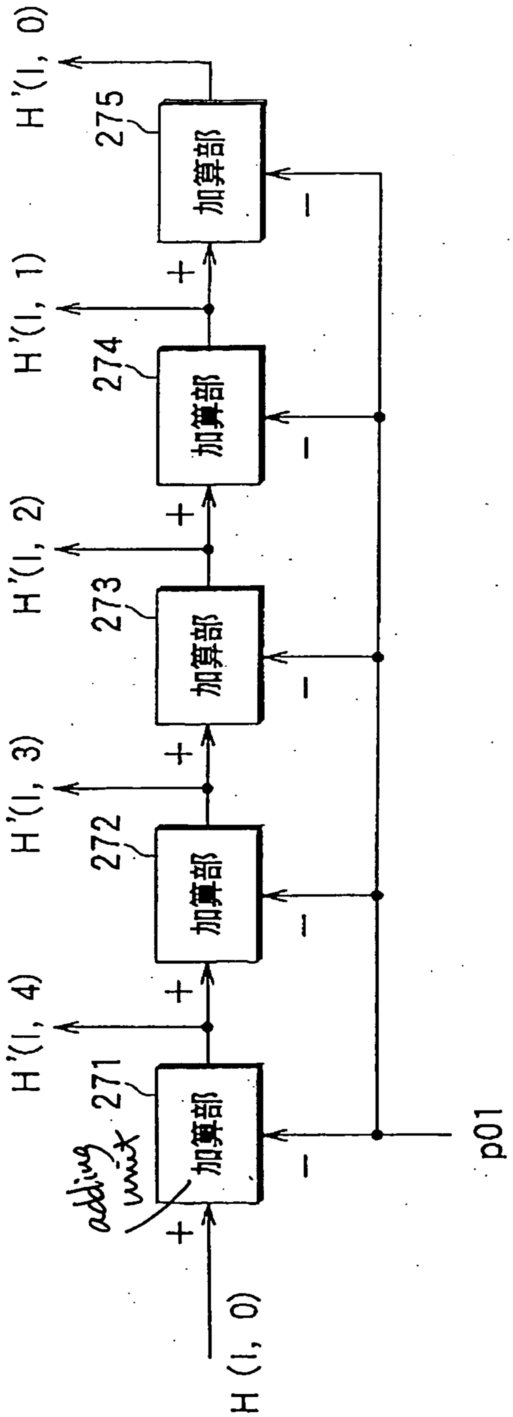

H(l, 0)
H(l, 1)
H(l, 2)
H(l, 3)
加算部
adding unit
21
22
23
−
+
÷14
÷13
24
25
26
p01
p12
p23
伝送路推定部
transmission path estimating unit
27
28
29
30
31
H'(l, 0)
H'(l, 4)
H'(l, 5)
H'(l, 17)
H'(l, 18)
H'(l, 29)
H'(l, 30)
H'(l, 42)
H'(l, 43)
H'(l, 47)

FIG. 3

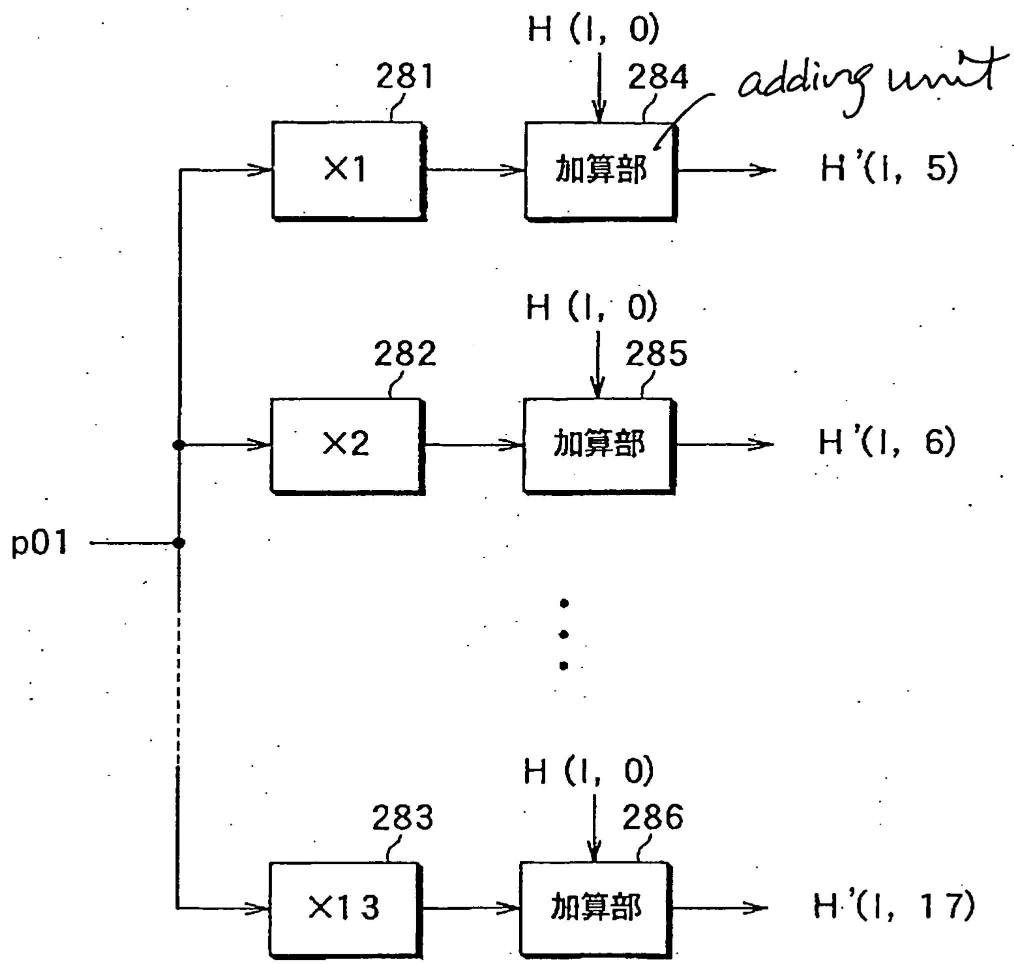
【図４】

FIG. 4


H'(I, 0)
275
加算部
H'(I, 1)
274
加算部
H'(I, 2)
273
加算部
H'(I, 3)
272
加算部
H'(I, 4)
271
加算部
adding unit
H (I, 0)
p01
+
−

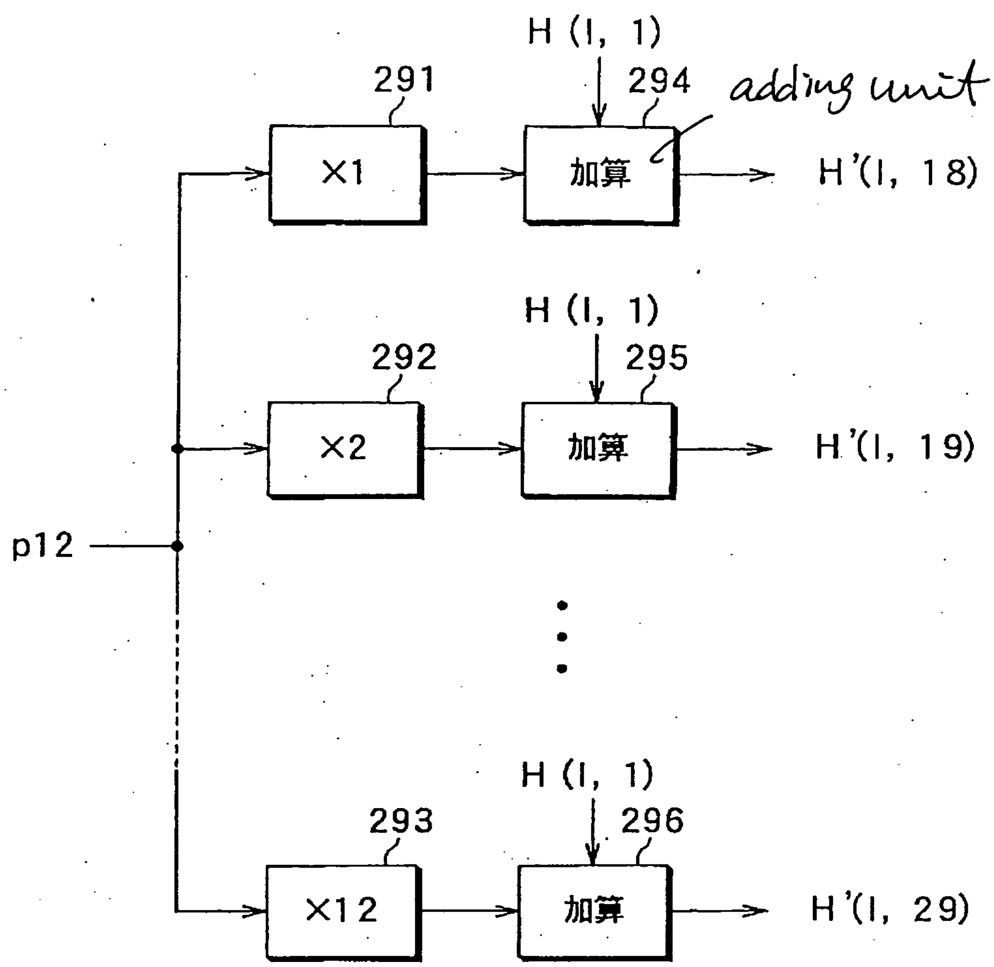
【図５】

FIG. 5


H (I, 0)
281
284
adding unit
×1
加算部
H'(I, 5)
H (I, 0)
282
285
×2
加算部
H'(I, 6)
p01
H (I, 0)
283
286
×13
加算部
H'(I, 17)

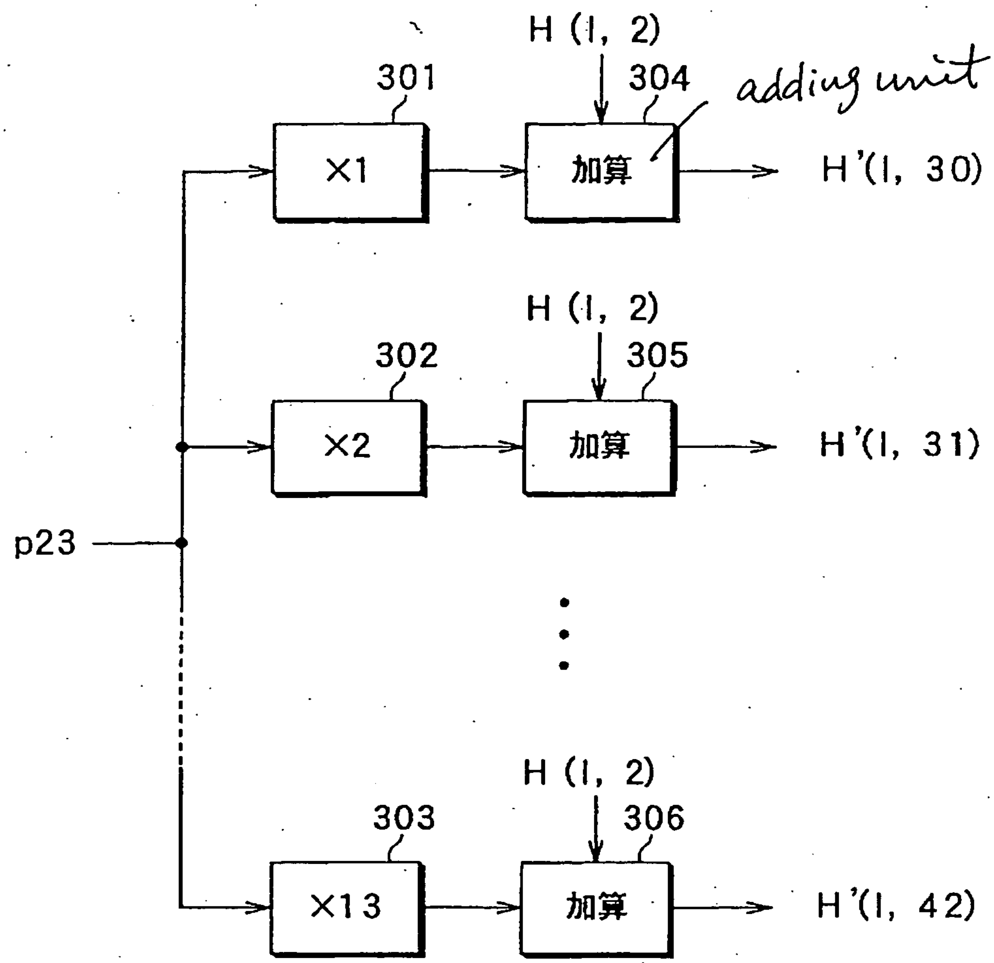
【図６】

FIG. 6


adding unit
H (I, 1)
291
294
×1
加算
H'(I, 18)
H (I, 1)
292
295
×2
加算
H'(I, 19)
p12
H (I, 1)
293
296
×12
加算
H'(I, 29)

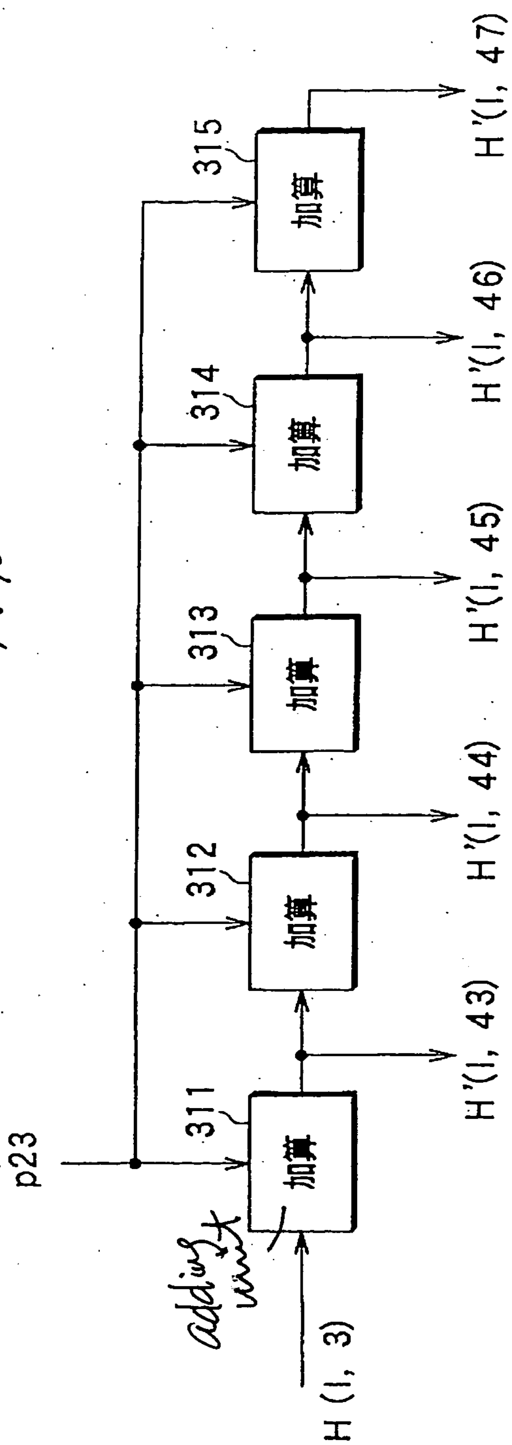
【図７】

FIG. 7


adding unit
H (I, 2)
301
304
×1
加算
H'(I, 30)
H (I, 2)
302
305
×2
加算
H'(I, 31)
p23
H (I, 2)
303
306
×13
加算
H'(I, 42)

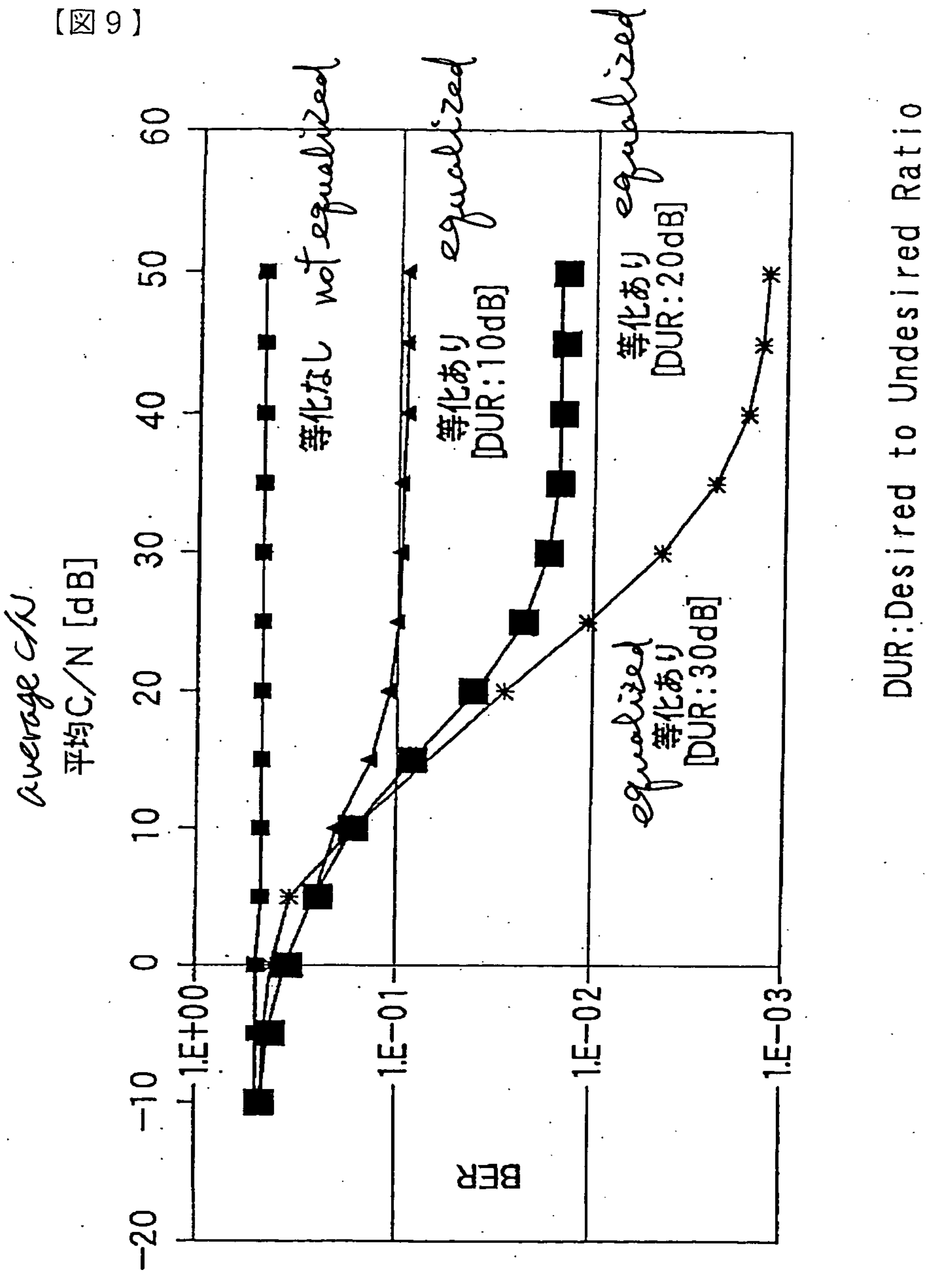
【図８】

FIG. 8


p23
H (I, 3)
adding unit
加算
311
312
313
314
315
H'(I, 43)
H'(I, 44)
H'(I, 45)
H'(I, 46)
H'(I, 47)

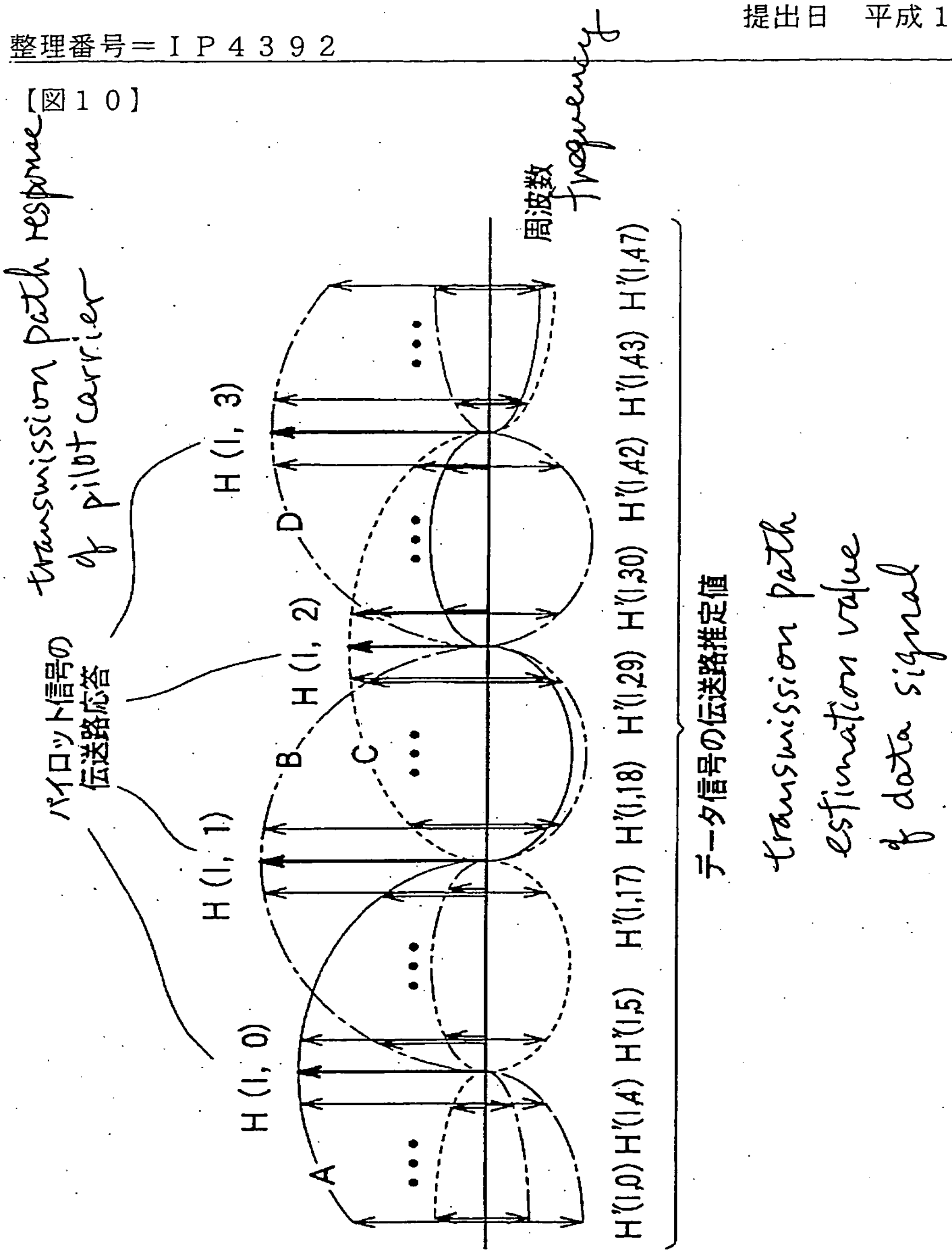
【図９】

FIG. 9


average C/N
平均C/N [dB]
BER
1.E+00
1.E-01
1.E-02
1.E-03
-20
-10
0
10
20
30
40
50
60
等化なし not equalized
等化あり [DUR:10dB] equalized
等化あり [DUR:20dB] equalized
等化あり [DUR:30dB] equalized
DUR:Desired to Undesired Ratio

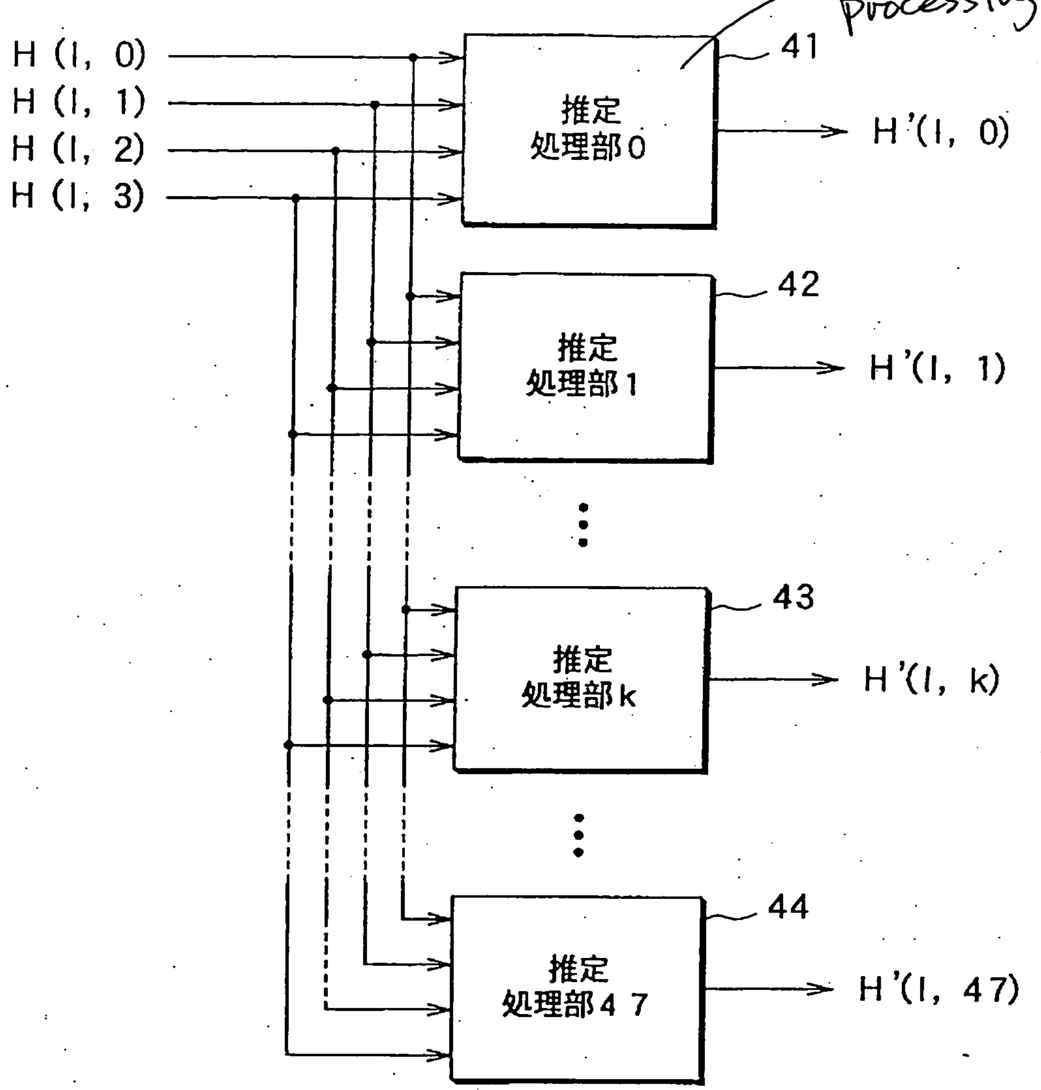
【図１０】

FIG. 10


パイロット信号の伝送路応答
transmission path response of pilot carrier
H (1, 0)
H (1, 1)
H (1, 2)
H (1, 3)
A
B
C
D
周波数
frequency
H'(1,0) H'(1,4) H'(1,5) H'(1,17) H'(1,18) H'(1,29) H'(1,30) H'(1,42) H'(1,43) H'(1,47)
データ信号の伝送路推定値
transmission path estimation value of data signal

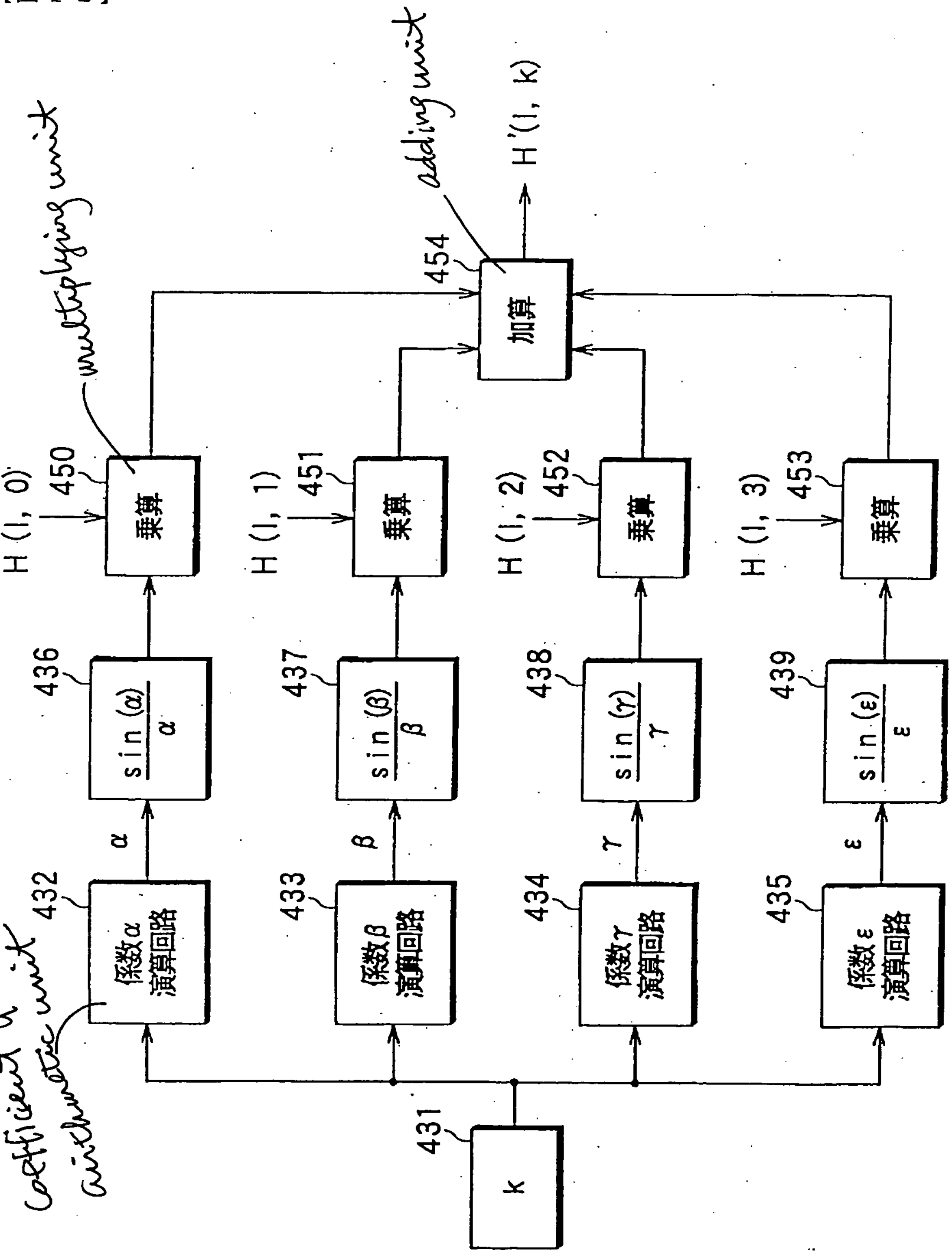
【図１１】

FIG. 11


estimation processing unit
H (I, 0)
H (I, 1)
H (I, 2)
H (I, 3)
41
推定
処理部０
H'(I, 0)
42
推定
処理部１
H'(I, 1)
43
推定
処理部ｋ
H'(I, k)
44
推定
処理部４７
H'(I, 47)

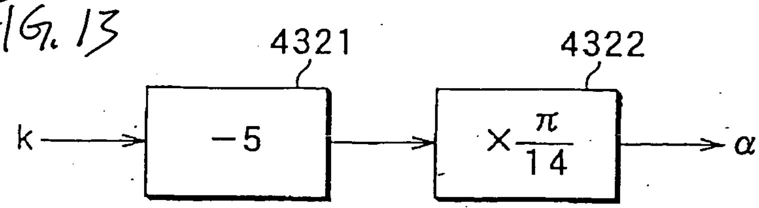
【図１２】

FIG.12


k
431
係数α演算回路
432
係数β演算回路
433
係数γ演算回路
434
係数ε演算回路
435
coefficient α arithmetic unit
α
β
γ
ε
436
437
438
439
sin(α)/α
sin(β)/β
sin(γ)/γ
sin(ε)/ε
H(I, 0)
H(I, 1)
H(I, 2)
H(I, 3)
乗算
450
451
452
453
multiplying unit
加算
454
adding unit
H'(I, k)

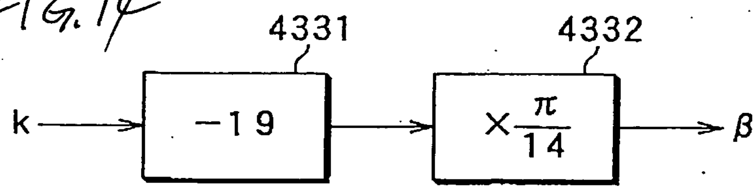
【図１３】

FIG. 13



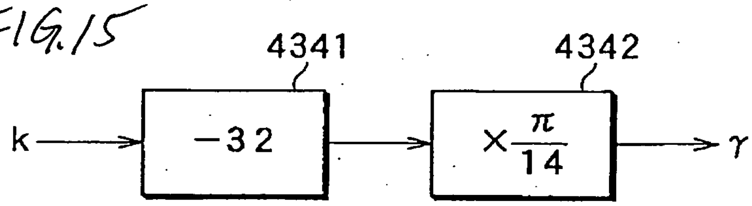
【図１４】

FIG. 14



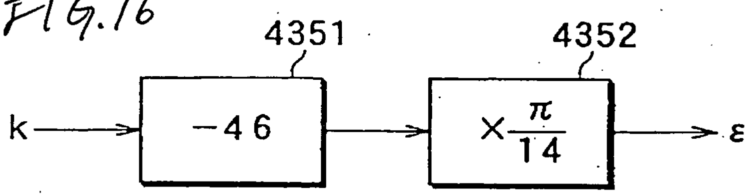
【図１５】

FIG. 15



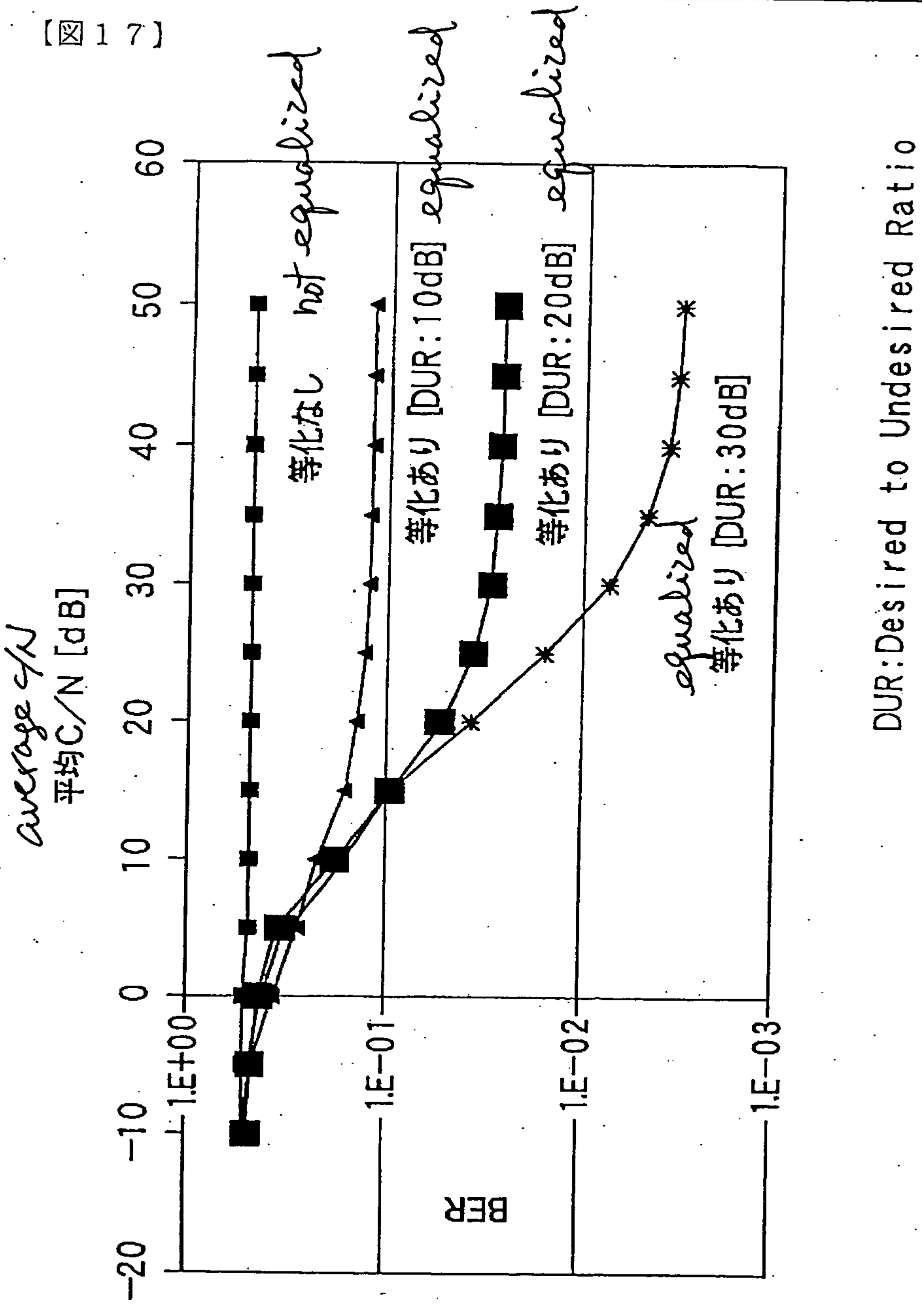
【図１６】

FIG. 16

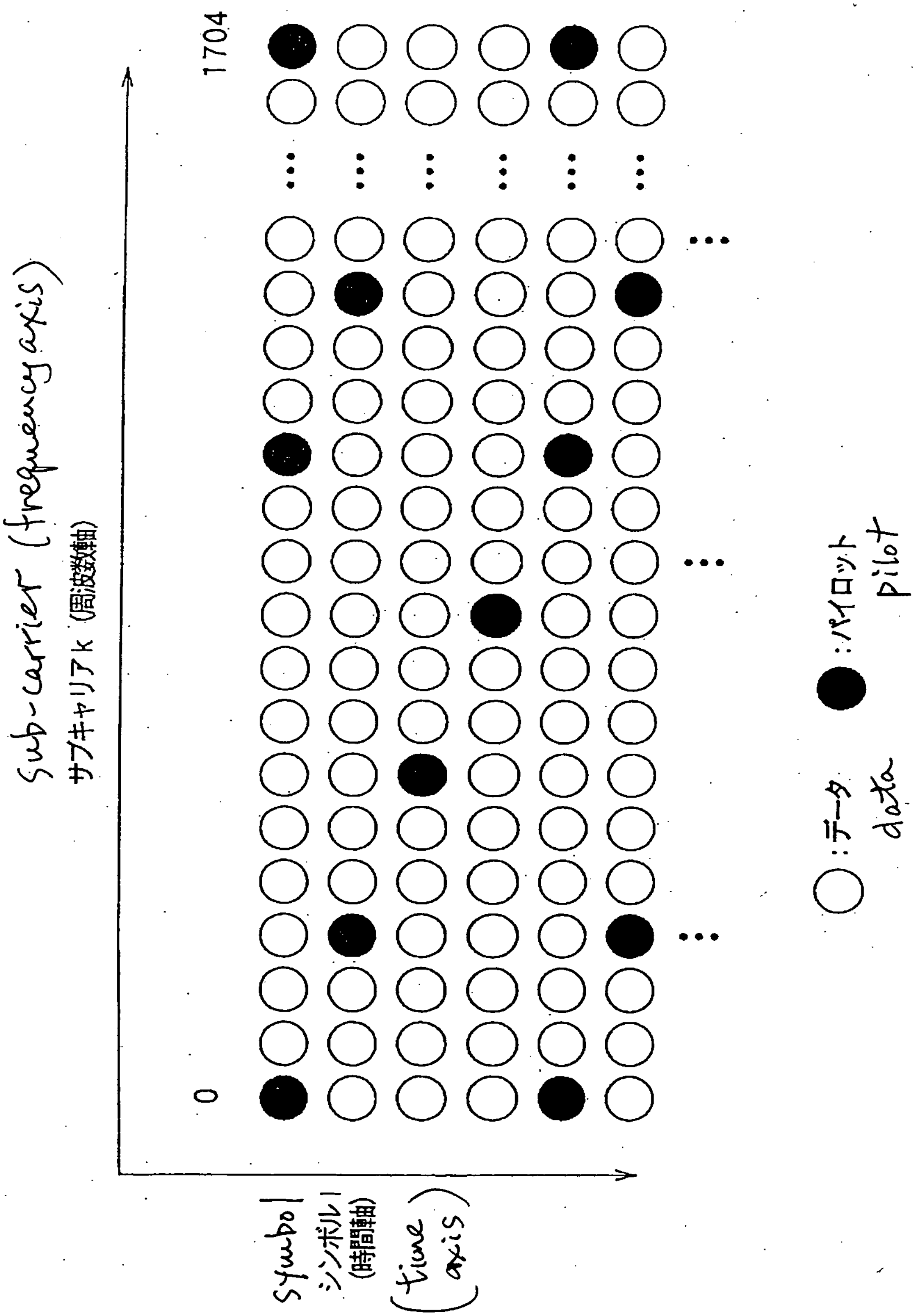


【図１７】

FIG. 17


average C/N
平均C/N [dB]
BER
1.E+00
1.E-01
1.E-02
1.E-03
-20
-10
0
10
20
30
40
50
60
等化なし
not equalized
等化あり [DUR:10dB]
equalized
等化あり [DUR:20dB]
equalized
等化あり [DUR:30dB]
equalized
DUR:Desired to Undesired Ratio

【図１８】


1704
0
Sub-carrier (frequency axis)
サブキャリアk (周波数軸)
symbol
シンボルl
(時間軸)
(time axis)
:データ
data
:パイロット
pilot

【図１９】

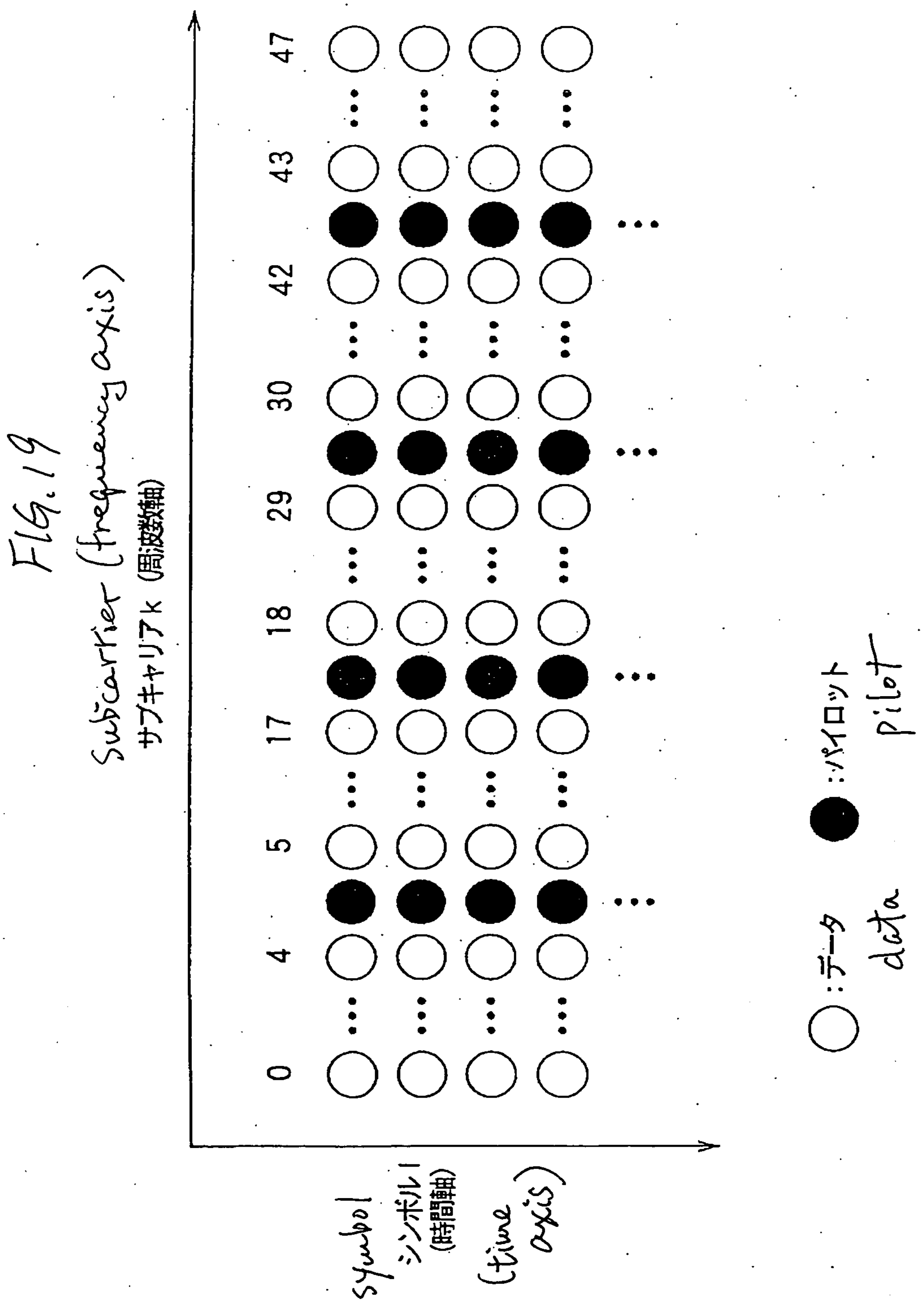


FIG. 19
Subcarrier (frequency axis)
サブキャリアk (周波数軸)
0
4
5
17
18
29
30
42
43
47
symbol
シンボル l
(時間軸)
(time axis)
:データ
data
:パイロット
pilot

[Name of the Document] Abstract Sheet

[Abstract]

[Object] To properly correct the amplitude and phase of received data signals relative to an OFDM signal format for MMAC.

After the OFDM signal for MMAC is received with a receiving unit, an FFT processing unit converts such OFDM signal into the signal Y(l, k) in the frequency axis direction. A data extracting unit extracts the data signal Y(l, kd) and a pilot extracting unit extracts the pilot signal Y(l, kp). A complex dividing unit divides the extracted pilot signal with the pilot signal X (l, kp) having the identical amplitude and phase as that in the transmitting side. The interpolating unit performs the linear interpolation with the transmission path response H(l, kp) of the calculated pilot signal in order to calculate the transmission path estimation value H' (l, k) of the data signal. A complex dividing unit divides the extracted data signal with the transmission path estimation value of the data signal in order to calculate the data signal Y' (l, kd) that is compensated in the amplitude and phase.

[Selected Figure] Fig. 1